Wind Erosion Research Accomplishments and Needs

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ABSTRACT

TREMENDOUS progress has been made in understanding the wind erosion process and the influence of the various soil and climatic parameters associated with wind erosion. A model has been developed that will estimate potential annual wind erosion. The opportunities for significant advancements in wind erosion are limited only by the vision of the scientist conducting the research. Major needs are the development of soil flux models for predicting erosion from single events, more dependable field wind erosion sampling equipment, identification of the impact of continued erosion on soil productivity, extension of benefit of emergency tillage, and optimization of barrier influence by designing the height-density-spacing of multiple barriers.

INTRODUCTION

Wind erosion is one of natures most subtle but persistent geomorphological processes. Man's cultivation of the land for the production of food and fiber has permitted wind erosion to become a problem in many areas of the world. The drought and "dust bowl" days of the 1930's dramatized the problem in the Great Plains states and stimulated the development of wind erosion research and control practices. Our objectives in this paper are to briefly present the developments in wind erosion research and describe the major problems needing additional research effort.

Wind erosion has attracted the attention of scientists for decades. A bibliography by Free (1911) contained 2,475 references on soil detachment and transport and phenomena related to wind and soil formation. Conservationists (Braken, 1921) noted that soil blowing was decreased by practices that increased soil cohesion (increasing soil moisture, increasing organic matter content, or soil structure modification), or by practices that protected the soil surface (high residue crops, stubble mulching, manure or straw applications, or wind breaks).

Joel (1937) after surveying 6,480,000 ha of the Southern Great Plains wind erosion area stated "Wind erosion is generally serious over the area, in many places alarming." He reported that 42.5 percent of the area was seriously damaged and an additional 40.5 percent damaged to some degree by wind erosion.

Wind erosion scientists recognized the need for a clear understanding of the physics involved in the lifting, transporting, and depositing of soil particles by wind. Consequently, the first concentrated research dealt with the dynamics of wind erosion.

Basic research on windblown soils was conducted by Bagnold (1936, 1943), Chepil and Milne (1939), and Malina (1941) and dealt primarily with wind velocity gradients over eroding soil surfaces. Results of this research showed that soil or sand moving in saltation decreased the momentum and the surface velocity of wind. Chepil (1943) expanded his early work into studies of surface structure stability and wind erodibility.

The USDA Wind Erosion Research Laboratory at Manhattan, KS, opened in the fall of 1947, provided an opportunity to concentrate on wind erosion problems. The laboratory wind tunnel (Zingg and Chepil, 1950), the portable wind tunnel and dust collector (Zingg, 1951), and the rotary sieve (Chepil, 1952) were specifically designed for wind erosion research. Soil moisture (Chepil, 1956), soil texture (Chepil, 1953), organic matter (Chepil, 1954), tillage (Chepil, et al. 1952; Woodruff and Chepil, 1956; Woodruff, et al. 1957), surface roughness (Chepil, 1950), and apparent density (Chepil, 1951) were tested individually to evaluate their influence on wind erosion. Results from these basic laboratory studies were combined with field wind-tunnel tests (Chepil, et al. 1955; Zingg, et al. 1953) to refine the early techniques of estimating wind erodibility (Chepil and Woodruff, 1954; 1959). These results were combined with data on wind velocity (Zingg, 1950), climatic factors (Zingg, 1953), and shelterbelts (Woodruff, 1956; Woodruff and Zingg, 1953; Woodruff and Zingg, 1955) to formulate the universal wind erosion equation (Niles, 1961). This equation expressed erosion in equivalent annual soil loss instead of relative field erodibility (Chepil, 1960).

The development of the universal equation for estimating potential annual wind erosion facilitated the testing of additional components and variables to further refine and strengthen the equation. Some of these factors included the combined influence of surface cloddiness and ridge roughness, and type and orientation of crop residues and crop barriers. The research through 1963 was discussed in an overview by Chepil and Woodruff (1963).

Research was conducted to evaluate the influence of prevailing wind direction (Chepil, et al., 1964), and rough and level terrain (Chepil et al., 1964) on estimated annual wind erosion. These results were consolidated into an updated version of the universal wind erosion equation (Woodruff and Siddoway, 1965). The equation is now used to determine potential erosion and to determine field conditions necessary to decrease potential erosion

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to a tolerable amount.

Wind erosion research then shifted to studies to refine the influence of tillage implements on soil erodibility (Lyles and Dickerson, 1967) and residue reduction (Fenster, et al. 1965; Woodruff, et al. 1965), to evaluate the influence of wind barriers on microclimate (Skidmore, et al. 1969; Skidmore, et al. 1966), and to test the relationship between wind erosion damage and crop growth (Armbrust, 1968; Fryrear and Downes, 1975; Fryrear and Downes, 1975; Skidmore, 1966). The wind erosion equation was modified to include a monthly climatic factor (Skidmore and Woodruff, 1968; Woodruff and Armbrust, 1968).

With this excellent base of wind erosion information, research was directed toward the physics involved in soil-particle movement. With more sophisticated equipment, new research was directed toward air turbulence and soil surface conditions (Lyles, et al. 1971; Lyles et al. 1974), windbreak influence (Hagen and Skidmore, 1971), and threshold velocities and soil movement (Lyles and Krauss, 1971).

Wind erosion research has not completely solved the problem. Sandyland farms in the central U.S., the muck soils area in the southeast, or the Palouse area of the northwest still have many problems and present many challenges in controlling wind erosion.

RESEARCH NEEDS

Since no single factor is responsible for continuing wind erosion, in this paper, we divided research needs and opportunities on the effects of erosion into: (a) the soil; (b) the crop; and (c) the environment. All of these factors are interrelated sometimes during the year.

Soils

The present wind erosion predictive equation estimates soil losses annually. To test various conservation practices or tillage systems, soil loss estimates are needed monthly or for each event. To obtain this information, additional research is needed to combine the various soil and crop parameters into a soil-flux model that will yield the soil erosion rate. Wind erosion scientists recognize that with present technology, the soil loss rate from a single storm on agricultural land cannot be computed with any degree of accuracy. Part of the problem is the lack of satisfactory wind erosion field sampling equipment as well as the complex nature of the processes involved in the initiation of soil movement, transport, and deposition. Opportunities in this area include development of soil flux equations that predict the influence of various soil, vegetative, and climatic parameters, and the incorporation of probability functions of the various dynamic parameters.

The most obvious method of controlling soil movement is by spraying soil binding chemicals on the soil surface (Lyles, et al. 1969). While economical for small areas, their cost prevented using them on crop fields. We need to continue searching for cheaper chemicals that could be used to control erosion in emergency conditions.

Wind erosion removes the silt, clay, and organic material from the soil. The long-term effects of wind erosion on the ability of a soil to produce a crop must be identified to conserve the soil resource. Tolerable soil loss rates for each soil series should include climatic, crop, and management factors.

Information is needed on the relationship of various tillage methods, timing, and operation on the erodibility of the soil surface. Research needs are as follows:

1 Identify the type of tillage implement to be used on various soil types, under varying soil moisture conditions, to increase surface roughness and clods resistance to breakdown by weathering and the abrasive action of windblown soil. These practices must be compatible with large farming equipment.

2 Develop techniques to extend the benefits from deep plowing and identify those soils and crops that would respond to deep plowing.

3 Identify the best emergency tillage methods for various soil, climatic, and crop management conditions.

Combine wind erosion control measures and water management or runoff control techniques into a complete farming system. In many areas wind and water erosion practices are not completely compatible because of the prevailing wind direction and the conflicting predominant field slope. We need to evaluate the complete system with an erosion model that recognizes the relationship of various control practices on potential erosion from both wind and water.

Crops

Additional research is needed to identify physiological response of plants to wind damage and critical levels of injury so plant survival and yield can be estimated. We need to identify the influence of environmental conditions after the exposure and determine to what extent the crop, soil, and environmental conditions can be modified to increase survival and decrease the impact on crop yield. Additional research is needed to develop methods of decreasing residue decomposition to maximize potential benefits of surface residues. Research on tillage implements that will decrease residue destruction is needed to identify the relationship between crop, soil, climatic conditions, and residue decomposition rates. We need to determine if residues are more effective on the surface or incorporated into the soil and to what extent residues can be retained on the surface under various cropping systems. Existing research on the critical friction velocity ratio of the various residue elements should be continued so cultural practices, like narrow-row or broadcast cropping, can be used to control wind erosion with minimum quantities of residue. We need to determine the relationship between type and orientation of surface residues and reduction in crop injury. Determine if residues are more effective concentrated in the crop row or uniformly distributed over the entire soil surface. Extremely erodible soils might be protected with a combination of wind barriers and surface residues or tillage. We need to determine optimum density and spacing of barriers used in combination with other conservation practices.

Environment

Environmental problems are probably the most difficult for wind erosion scientists to study, primarily because of their limited training in climatology or meteorology. Research is needed to identify the total contribution of wind erosion to air-particle concentrations. We need to determine the composition of material eroded from farm fields and to identify the extent and type of chemicals attached to eroded particles. We also need to know the impact of wind erosion on global climatic conditions. Limited research has shown that there is a relationship between eroded particulate matter from the Sahara region and the incidence of severe tropical storms in the Caribbean (Carlson and Prospero, 1972). We need to determine the impact of soil particle accumulation on the soil formation process and identify the hazards of blowing dust across highways and how it can be reduced. We need to cooperate with veterinarians and physicians, and with air pollution engineers to determine the effect of suspended soil particles on animal and human health.

SUMMARY

Past wind erosion research has provided many valuable tools in identifying wind erosion losses and practices to decrease the wind erosion hazard. There are many remaining research opportunities to make significant contributions to decrease the impact of wind erosion on the farmer, the urban resident, and the environment.

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